Form A2-3: Compliance Verification Report for Inverter Connected Power Generating Modules

This form should be used by the **Manufacturer** to demonstrate and declare compliance with the requirements of EREC G99. The form can be used in a variety of ways as detailed below:

1. To obtain **Fully Type Tested** status

   The **Manufacturer** can use this form to obtain **Fully Type Tested** status for a **Power Generating Module** by registering this completed form with the Energy Networks Association (ENA) Type Test Verification Report Register.

2. To obtain **Type Tested** status for a product

   This form can be used by the **Manufacturer** to obtain **Type Tested** status for a product which is used in a **Power Generating Module** by registering this form with the relevant parts completed with the Energy Networks Association (ENA) Type Test Verification Report Register.

3. One-off Installation

   This form can be used by the **Manufacturer** or **Installer** to confirm that the **Power Generating Module** has been tested to satisfy all or part of the requirements of this EREC G99. This form must be submitted to the **DNO** as part of the application.

A combination of (2) and (3) can be used as required, together with Form A2-4 where compliance of the **Interface Protection** is to be demonstrated on site.

Note:

Within this Form A2-3 the term **Power Park Module** will be used but its meaning can be interpreted within Form A2-3 to mean **Power Park Module**, **Generating Unit or Inverter** as appropriate for the context. However, note that compliance must be demonstrated at the **Power Park Module** level.

If the **Power Generating Module** is **Fully Type Tested** and registered with the Energy Networks Association (ENA) Type Test Verification Report Register, the Installation Document (Form A3) should include the **Manufacturer's** reference number (the Product ID), and this form does not need to be submitted.

Where the **Power Generating Module** is not registered with the ENA Type Test Verification Report Register or is not **Fully Type Tested** this form (all or in parts as applicable) needs to be completed and provided to the **DNO**, to confirm that the **Power Generating Module** has been tested to satisfy all or part of the requirements of this EREC G99.

PGM technology		***For All C200R, C200S incorporated Systems***	
Manufacturer name		Capstone Turbine Corporation	
Address		16640 Stagg Street Van Nuys, CA91406	
Tel	+1 866 422 7786	Web site	www.capstoneturbine.com
E:mail	service@capstoneturbine.com		
Registered Capacity		200kW	

There are four options for Testing: (1) **Fully Type Tested**, (2) Partially **Type Tested**, (3) one-off installation, (4) tested on site at time of commissioning. The check box below indicates which tests in this Form have been completed for each of the options. With the exception of **Fully Type Tested PGMs** tests marked with * may be carried out at the time of commissioning (Form A4).

Tested option:	**1. Fully Type Tested**	**2. Partially Type Tested**	**3. One-off Man. Info.**	**4. Tested on Site at time of Commission-ing**
0. **Fully Type Tested** - all tests detailed below completed and evidence attached to this submission	**Yes**	**N/A**	**N/A**	**N/A**
1. Operating Range	**N/A**			
2. PQ – Harmonics				
3. PQ – Voltage Fluctuation and Flicker				
4. PQ – DC Injection (**Power Park Modules** only)				
5. **Power Factor** (PF)*				
6. Frequency protection trip and ride through tests*				
7. Voltage protection trip and ride through tests*				
8. Protection – Loss of Mains Test*, Vector Shift and RoCoF Stability Test*				
9. **LFSM-O** Test*				
10. Protection – Reconnection Timer*				
11. Fault Level Contribution				
12. Self-monitoring Solid State Switch				
13. Wiring functional tests if required by para 15.2.1 (attach relevant schedule of tests)*				
14. Logic Interface (input port)*				

* may be carried out at the time of commissioning (Form A.2-4).

Document reference(s) for **Manufacturers' Information:**

Manufacturer compliance declaration. - I certify that all products supplied by the company with the above **Type Tested Manufacturer's** reference number will be manufactured and tested to ensure that they perform as stated in this document, prior to shipment to site and that no site **Modifications** are required to ensure that the product meets all the requirements of EREC G99.

Signed	 Digitally signed by Paul Keates DN: cn=Paul Keates, o=Capstone, ou=UK, email=pkeates@capstoneturbine.com, c=GB Date: 2019.08.01 08:38:59 +01'00'	On behalf of	Capstone Turbine Corporation

Note that testing can be done by the **Manufacturer** of an individual component or by an external test house.

Where parts of the testing are carried out by persons or organisations other than the **Manufacturer** then that person or organisation shall keep copies of all test records and results supplied to them to verify that the testing has been carried out by people with sufficient technical competency to carry out the tests.

A2-3 Compliance Verification Report –Tests for Type A Inverter Connected Power Generating Modules – test record

1. Operating Range: Two tests should be carried with the **Power Generating Module** operating at **Registered Capacity** and connected to a suitable test supply or grid simulation set. The power supplied by the primary source shall be kept stable within ± 5 % of the apparent power value set for the entire duration of each test sequence.

Frequency, voltage and **Active Power** measurements at the output terminals of the **Power Generating Module** shall be recorded every second. The tests will verify that the **Power Generating Module** can operate within the required ranges for the specified period of time.

The **Interface Protection** shall be disabled during the tests.

In case of a PV **Power Park Module** the PV primary source may be replaced by a DC source.

In case of a full converter **Power Park Module** (eg wind) the primary source and the prime mover I**nverter**/rectifier may be replaced by a DC source.

Test 1 Voltage = 85% of nominal (195.5 V), Frequency = 47 Hz, **Power Factor** = 1, Period of test 20 s	Always connected
Test 2 Voltage = 85% of nominal (195.5 V), Frequency = 47.5 Hz, **Power Factor** = 1, Period of test 90 minutes	Always connected
Test 3 Voltage = 110% of nominal (253 V)., Frequency = 51.5 Hz, **Power Factor** = 1, Period of test 90 minutes	Always connected
Test 4 Voltage = 110% of nominal (253 V), Frequency = 52.0 Hz, **Power Factor** = 1, Period of test 15 minutes	Always connected

2. Power Quality – Harmonics:

For **Power Generating Modules** of **Registered Capacity** of less than 75 A per phase (ie 50 kW) the test requirements are specified in Annex A.7.1.5**.** These tests should be carried out as specified in BS EN 61000-3-12 The results need to comply with the limits of Table 2 of BS EN 61000-3-12 for single phase equipment and Table 3 of BS EN 610000-3-12 for three phase equipment.
Power Generating Modules with emissions close to the limits laid down in BS EN 61000-3-12 may require the installation of a transformer between 2 and 4 times the rating of the **Power Generating Module** in order to accept the connection to a **Distribution Network.**
For **Power Generating Modules** of **Registered Capacity** of greater than 75 A per phase (ie 50 kW) the installation must be designed in accordance with EREC G5.

Power Generating Module tested to BS EN 61000-3-12						
Power Generating Module rating per phase (rpp)				kVA	Harmonic % = Measured Value (A) x 23/rating per phase (kVA)	
Harmonic	At 45-55% of **Registered Capacity**		100% of **Registered Capacity**		Limit in BS EN 61000-3-12	
	Measured Value MV in Amps	%	Measured Value MV in Amps	%	1 phase	3 phase
2	0.54	0.36	0.66	0.22	8%	8%
3	0.195	0.13	0.45	0.15	21.6%	Not stated
4	0.6	0.4	0.72	0.24	4%	4%
5	0.255	0.17	1.08	0.36	10.7%	10.7%
6	0.075	0.05	0.15	0.05	2.67%	2.67%
7	0.06	0.04	0.87	0.29	7.2%	7.2%
8	0.12	0.08	0.06	0.02	2%	2%
9	0.06	0.04	0.21	0.07	3.8%	Not stated
10	0.225	0.15	0.45	0.15	1.6%	1.6%
11	0.24	0.16	0.45	0.15	3.1%	3.1%
12	0.015	0.01	0.06	0.02	1.33%	1.33%
13	0.21	0.14	0.45	0.15	2%	2%
THD[1]					23%	13%
PWHD[2]					23%	22%

[1] THD = Total Harmonic Distortion

[2] PWHD = Partial Weighted Harmonic Distortion

3. Power Quality – Voltage fluctuations and Flicker:

For **Power Generating Modules** of **Registered Capacity** of less than 75 A per phase (ie 50 kW) these tests should be undertaken in accordance with Annex A.7.1.4.3. Results should be normalised to a standard source impedance, or if this results in figures above the limits set in BS EN 61000-3-11 to a suitable Maximum Impedance.

For **Power Generating Modules** of **Registered Capacity** of greater than 75 A per phase (ie 50 kW) the installation must be designed in accordance with EREC P28.

	Starting			Stopping			Running	
	d max	d c	d(t)	d max	d c	d(t)	P st	P lt 2 hours
Measured Values at test impedance								
Normalised to standard impedance								
Normalised to required maximum impedance								
Limits set under BS EN 61000-3-11	4%	3.3%	3.3%	4%	3.3 %	3.3%	1.0	0.65

Test Impedance	R		Ω	Xl		Ω
Standard Impedance	R	0.24 * 0.4 ^	Ω	Xl	0.15 * 0.25 ^	Ω
Maximum Impedance	R		Ω	Xl		Ω

* Applies to three phase and split single phase **Power Generating Modules.**

^ Applies to single phase **Power Generating Module** and **Power Generating Modules** using two phases on a three phase system

For voltage change and flicker measurements the following formula is to be used to convert the measured values to the normalised values where the **Power Factor** of the generation output is 0.98 or above.

Normalised value = Measured value x reference source resistance/measured source resistance at test point

Single phase units reference source resistance is 0.4 Ω

Two phase units in a three phase system reference source resistance is 0.4 Ω Two phase units in a split phase system reference source resistance is 0.24 Ω Three phase units reference source resistance is 0.24 Ω Where the **Power Factor** of the output is under 0.98 then the Xl to R ratio of the test impedance should be close to that of the Standard Impedance. The stopping test should be a trip from full load operation. The duration of these tests need to comply with the particular requirements set out in the testing notes for the technology under test. Dates and location of the test need to be noted below			
Test start date	Nov 10th 2014	Test end date	Dec 4th 2014
Test location	Capstone Turbine Corporation 16640 Stagg Street, Van Nuys, CA 91406		

4. Power quality – DC injection: The tests should be carried out on a single **Generating Unit**. Tests are to be carried out at three defined power levels ±5%. At 230 V a 50 kW three phase **Inverter** has a current output of 217 A so DC limit is 543 mA. These tests should be undertaken in accordance with Annex A.7.1.4.4.			
Test power level	10%	55%	100%
Recorded value in Amps	0.02 0.04 0.04	0.02 0.06 0.06	0.08 0.06 0.02
as % of rated AC current	0.13	0.013	0.027
Limit	0.25%	0.25%	0.25%
5. Power Factor: The tests should be carried out on a single **Power Generating Module**. Tests are to be carried out at three voltage levels and at **Registered Capacity**. Voltage to be maintained within ±1.5% of the stated level during the test. These tests should be undertaken in accordance with Annex A.7.1.4.2.			
Voltage	0.94 pu (216.2 V)	1 pu (230 V)	1.1 pu (253 V)
Measured value	1	1	1
Power Factor Limit	>0.95	>0.95	>0.95

6. Protection – Frequency tests: These tests should be carried out in accordance with the Annex A.7.1.2.3.

Function	Setting		Trip test		"No trip tests"	
	Frequency	Time delay	Frequency	Time delay	Frequency /time	Confirm no trip
U/F stage 1	47.5 Hz	20 s	L1 47.503 L2 47.503 L3 47.503	20.135s	47.7 Hz 25 s	Confirmed

U/F stage 2	47 Hz	0.5 s	L1 47.001 L2 47.001 L3 47.001	0.505s	47.2 Hz 19.98 s	Confirmed
					46.8 Hz 0.48 s	Confirmed
O/F	52 Hz	0.5 s	L1 51.991 L2 51.991 L3 51.991	0.52s	51.8 Hz 89.98 s	Confirmed
					52.2 Hz 0.48 s	Confirmed
Note. For frequency trip tests the frequency required to trip is the setting ± 0.1 Hz. In order to measure the time delay a larger deviation than the minimum required to operate the projection can be used. The "No trip tests" need to be carried out at the setting ± 0.2 Hz and for the relevant times as shown in the table above to ensure that the protection will not trip in error.						
7. Protection – Voltage tests: These tests should be carried out in accordance with Annex A.7.1.2.2.						
Function	Setting		Trip test		"No trip tests"	
	Voltage	Time delay	Voltage	Time delay	Voltage /time	Confirm no trip
U/V	0.8 pu (184 V)	2.5 s	L1 185.443 L2 185.106 L3 184.49	2.63s	188 V 3.50 s	Confirmed
					180 V 2.48 s	Confirmed
O/V stage 1	1.14 pu (262.2 V)	1.0 s	L1 263.34 L2 263.281 L3 273.339	1.06s	258.2 V 2.0 s	Confirmed
O/V stage 2	1.19 pu (273.7 V)	0.5 s	L1 274.714 L2 274.558 L3 274.739	0.55s	269.7 V 0.98s	Confirmed
					277.7 V 0.48 s	Confirmed
Note for Voltage tests the Voltage required to trip is the setting ±3.45 V. The time delay can be measured at a larger deviation than the minimum required to operate the protection. The No trip tests need to be carried out at the setting ±4 V and for the relevant times as shown in the table above to ensure that the protection will not trip in error.						

8.Protection – Loss of Mains test: These tests should be carried out in accordance with BS EN 62116. Annex A.7.1.2.4.						
The following sub set of tests should be recorded in the following table.						
Test Power and imbalance	33% -5% Q Test 22	66% -5% Q Test 12	100% -5% P Test 5	33% +5% Q Test 31	66% +5% Q Test 21	100% +5% P Test 10
Trip time. Limit is 0.5s	0.161s	0.152s	0.16s	0.158s	0.156s	0.155s

Loss of Mains Protection, Vector Shift Stability test. This test should be carried out in accordance with Annex A.7.1.2.6.			
	Start Frequency	Change	Confirm no trip
Positive Vector Shift	49.5 Hz	+50 degrees	Confirmed
Negative Vector Shift	50.5 Hz	- 50 degrees	Confirmed

Loss of Mains Protection, RoCoF Stability test: This test should be carried out in accordance with Annex A.7.1.2.6.			
Ramp range	Test frequency ramp:	Test Duration	Confirm no trip
49.0 Hz to 51.0 Hz	+0.95 Hzs^{-1}	2.1 s	Confirmed
51.0 Hz to 49.0 Hz	-0.95 Hzs^{-1}	2.1 s	Confirmed

9. Limited Frequency Sensitive Mode – Over frequency test: The test should be carried out using the specific threshold frequency of 50.4 Hz and **Droop** of 10%. This test should be carried out in accordance with Annex A.7.1.3.	
Active Power response to rising frequency/time plots are attached if frequency injection tests are undertaken in accordance with Annex A.7.2.4.	**Y/N**
Alternatively, simulation results should be noted below:	

Test sequence at **Registered Capacity** >80%	Measured **Active Power** Output	Frequency	Primary Power Source	**Active Power** Gradient
Step a) 50.00Hz ±0.01Hz	173.920kW	50		-0
Step b) 50.45Hz ±0.05Hz	170.304kW	50.25		-2% (-40% per 1hz)
Step c) 50.70Hz ±0.10Hz	138.948kW	50.70		-20% (-40% per 1hz)
Step d) 51.15Hz ±0.05Hz	107.776kW	51.15		-38% (-40% per 1 hz)
Step e) 50.70Hz ±0.10Hz	107.735kW	50.07		-sustained
Step f) 50.45Hz ±0.05Hz				-

Step g) 50.00Hz ±0.01Hz	173.813kW	50		-0
Test sequence at **Registered Capacity** 40% - 60%	Measured **Active Power** Output	Frequency	Primary Power Source	**Active Power** Gradient
Step a) 50.00Hz ±0.01Hz	99.550kW	50		-0
Step b) 50.45Hz ±0.05Hz	97.370kW	50.25		-2% (-40% per 1hz)
Step c) 50.70Hz ±0.10Hz	79.568kW	50.7		-20% (-40% per 1hz)
Step d) 51.15Hz ±0.05Hz	61.657kW	51.15		-38% (-40% per 1 hz)
Step e) 50.70Hz ±0.10Hz	61.750kW	50.07		-sustained

10. Protection – Re-connection timer.

Test should prove that the reconnection sequence starts after a minimum delay of 20 s for restoration of voltage and frequency to within the stage 1 settings of Table 10.1.

Time delay setting	Measured delay	Checks on no reconnection when voltage or frequency is brought to just outside stage 1 limits of Table 10.1.			
5mins	300s	At 1.16 pu (266.2 V)	At 0.85 pu (196.1 V)	At 47.4 Hz	At 52.1 Hz
Confirmation that the **Power Generating Module** does not re-connect.		confirmed	confirmed	confirmed	confirmed

11. Fault level contribution: These tests shall be carried out in accordance with EREC G99 Annex A.7.1.5.

For **Inverter** output

Time after fault	Volts	Amps
20ms	0	0
100ms	0	0
250ms	0	0
500ms	0	0
Time to trip	0.0102mS	In seconds

12. Self-Monitoring solid state switching: No specified test requirements. Refer to Annex A.7.1.7.	
It has been verified that in the event of the solid state switching device failing to disconnect the **Power Park Module**, the voltage on the output side of the switching device is reduced to a value below 50 volts within 0.5 s.	Yes/ ~~NA~~
13. Wiring functional tests: If required by para 15.2.1.	
Confirm that the relevant test schedule is attached (tests to be undertaken at time of commissioning)	Yes / NA
14. Logic interface (input port).	
Confirm that an input port is provided and can be used to shut down the module.	Yes / ~~NA~~
Additional comments.	

System designed iaw EREC G5, and P28.

3. Voltage flicker tests passed, please see attached data.

5. Power factor:
Reactive current is used to provide a trip of loss of current if one phase is removed (it is detectable). So with no real power we still push reactive current in order to detect loss of single phase. This will be detectable at low power outputs.

9. Power reduction gradient results used were set to 40% droop. Configurable from 0% through 60%. For G99 this is set to 10% droop.

11. Fault level contribution peaked at 840A for ½ cycle (8.6mS)

12. solid state IGBT switching device is zero within 400mS and is also isolated via the output contactor (0 within 180mS), annex A.7.1.7 not yet written to define test.

14. Input port can be always digital i/o or often with the option of Modbus depending on installation.

Explain the PGU's behavior from the generator perspective during a LVFRT event:

During a low voltage fault ride through event, the Load Control Module (LCM) ceases to output direct current and ramps in reactive current. The Micro Turbine engine and generator continue to generate power during this event. In this instance, the Generator Control Module (GCM) continues to support the AC-to-DC output to maintain the internal DC bus between the GCM and LCM, but the GCM will also deliver power through IGBT switching mechanism into an internal brake resistor assembly. This brake resistor assembly is rated to absorb the power and expel the heat created by the engine & generator for the duration of the low voltage ride through event. Once the grid voltage is restored to nominal level, the GCM ceases to feed power to the brake resistor, and only feeds power to the internal DC bus in support of the LCM to export active power back to the utility grid.